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THE DIVERSIFICATION OF THE CANE SUGAR INDUSTRY IN LATIN AMERICA AND THE CARIBBEAN*

Prepared by

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Introduction

The cane sugar industry was established in most of the Latin American and Caribbean countries after the colonial period and from then onwards these countries began to face sugar price fluctuations on the international market.

The sugar industry in the region comprises some 650 factories with a value of more than $US 15 billion. Output is approximately 30 million tons of sugar. In their technical level, the sugar factories lag behind the development of other industrial branches. Their technical obsolescence, the low level of maintenance and replacement and their special situation with regard to the use of fuel resources leave ample scope for improving efficiency and reducing costs.

Sugar-cane offers enormous possibilities for integrated processing by the industrial use of its by-products for the production of derivatives, with the aid of which it is possible to solve a number of problems that confront the countries such as demand for pulp and paper, boards, animal feed, and fuel requirements, generating income from export and/or import substitution.

In the context of a diversification strategy one can immediately envisage a whole range of possibilities offered by sugar cane in addition to the as yet unused potential of by-products, which is of fundamental importance in an industrial reorganization analysis.

With an output of 30 million tons of sugar, the volume of by-products generated by the regional sugar industry can help to solve demand for feedstuffs, fuels, pulp and paper, board, resins, plastics and other products.

Table 1

By-products obtainable with an
output of 30 million tons of sugar

BY-PRODUCTS	MILLION TONS
Bagasse, 50% moisture	66
Final molasses, 80° Brix	9
Filter cake, 77% moisture	9
Green leaves	25
Dry leaves	22
Cane top (green stalk)	22

Source: GEPLACEA - 1986

These figures show that the region has a broad raw materials base for the development and industrial processing of many products by the use of which the sugar sector can be diversified and expanded.

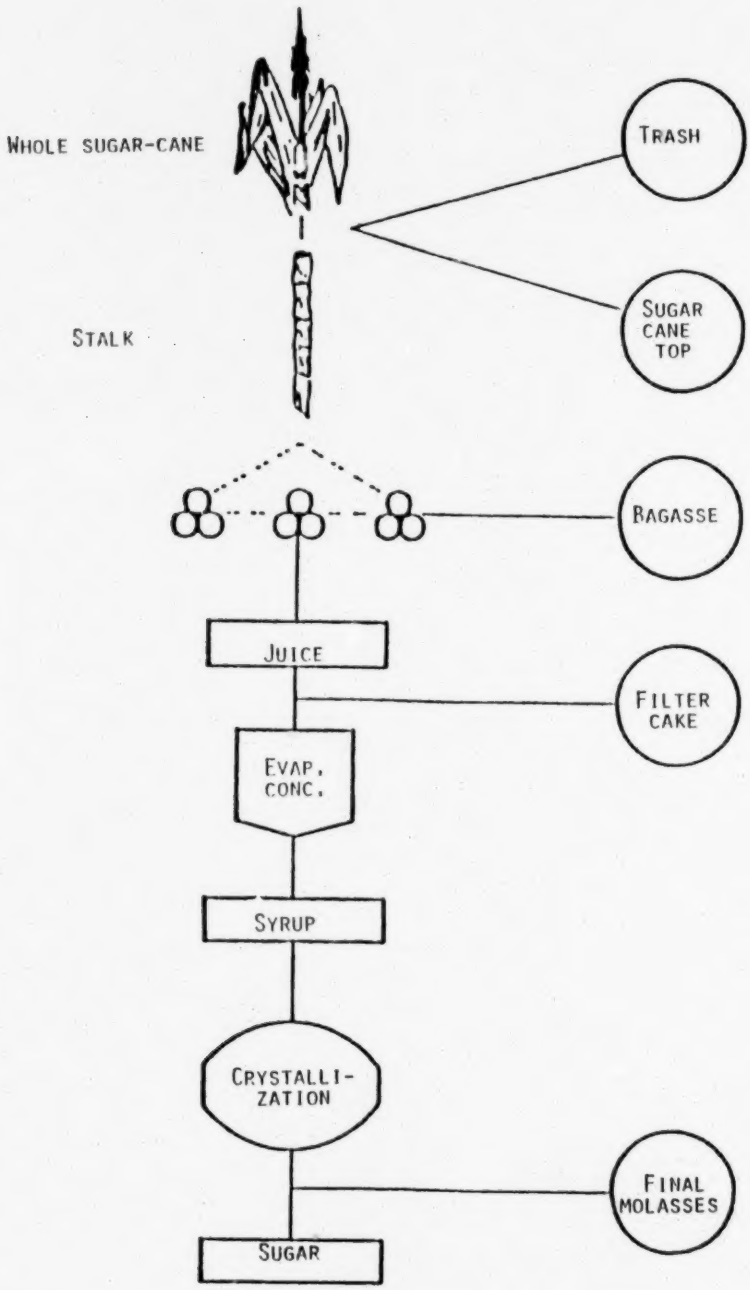
The purpose of the present paper is to show the development with regard to by-products that has been achieved in the region and the possibilities that are offered by diversification of the cane sugar industry.

1. By-products of the cane sugar industry and sugar-cane derivatives

Many by-products are obtained in sugar manufacture; they can be grouped according to the stage at which they occur, namely, those obtained during the harvesting of the cane, comprising green leaves, dry leaves, cane tops and fragments of sugar cane, commonly called harvest waste, and those that occur during the industrial process, such as molasses, bagasse and filter cake.

Figure 1

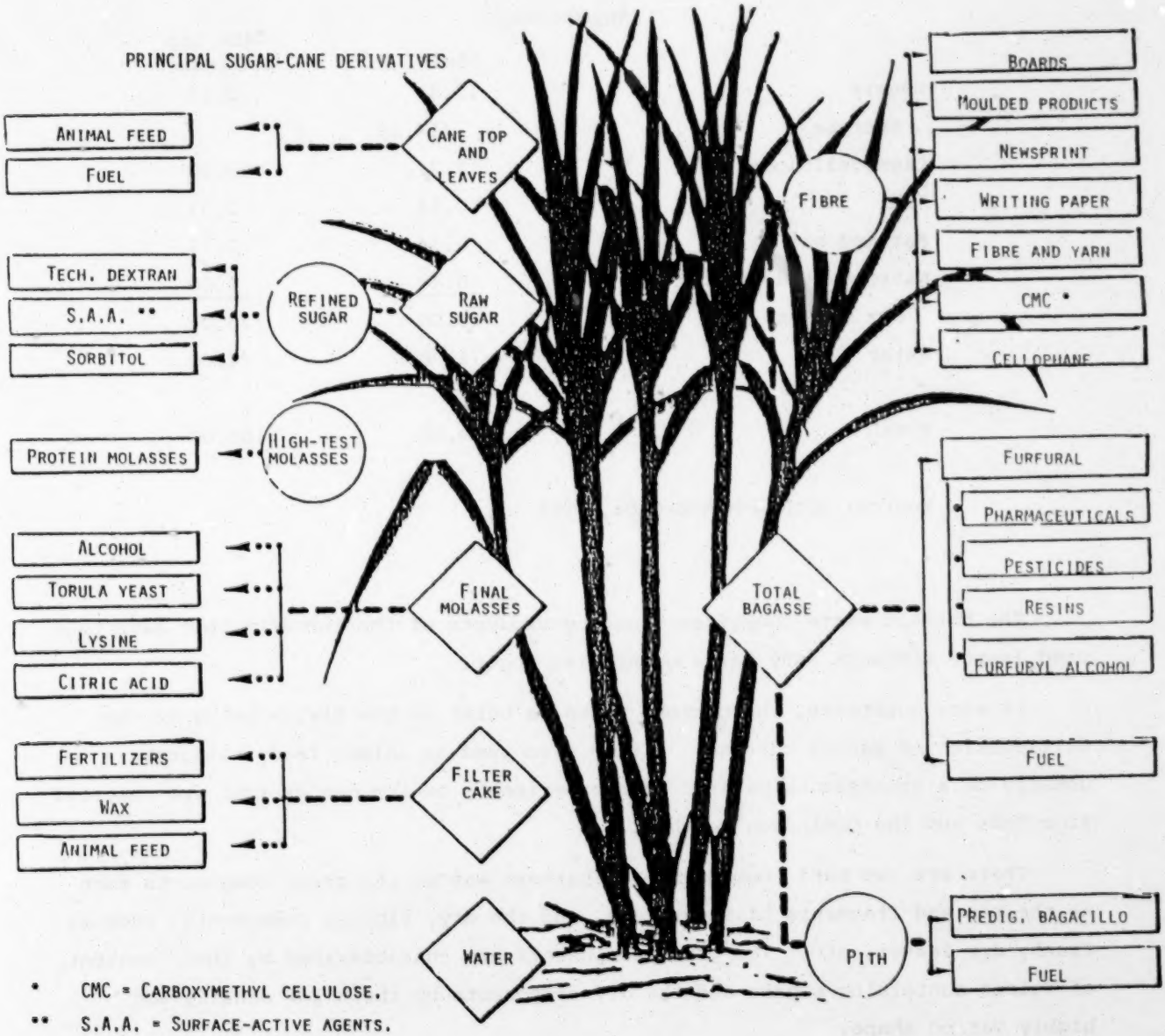
By-products of the cane sugar industry



Sugar-cane derivatives are defined as products that are obtained industrially from the by-products of the cane sugar industry: for example, molasses is a by-product and alcohol and torula yeast are derivatives obtained from the by-product molasses.

Figure 2, prepared by ICIDCA-MINAZ-Cuba, shows the by-products of the cane sugar industry as well as the main sugar-cane derivatives.

Figure 2



Sugar-cane consists basically of sugar, chiefly sucrose, and structural carbohydrates from the lignocellulosic complex, which have different uses. The saccharides of the sugar-cane yield intermediate or final products by fermentation or chemical means that have many possible uses in agriculture and cattle-rearing, the food, chemical, pharmaceutical and other industries. The lignocellulosic complex consists basically of cellulose, lignine and pentosans; it is possible to use these for the production of pulp and paper, boards, fuel, other by-products and for electricity generation.

Table 2

PERCENTAGE COMPOSITION OF SUGAR-CANE

(Approximate)

	Stalk	Cane top and leaves
Sugars	15.43	2.18
Sucrose	(14.1)	
Lignocellulose	12.21	19.08
Ash	0.54	2.31
Fat and wax	0.34	0.77
Nitrogenated compounds	0.48	1.66
Dry matter	29.00	26.00
Water	71.00	74.00
TOTAL	100.00	100.00

Source: ICIDCA-MINAZ-Cuba. 1985

The harvest waste comprises those by-products of the industry that have been used least, although very large quantities occur.

In many countries, the harvest waste is burnt on the fields owing to the difficulties of manual cutting. It is also used as animal feed, although usually on a spontaneous basis. Some experiments on its use as fuel are reported from Cuba and the Dominican Republic.

There are two basic components of harvest waste: the green components such as the top and fragments of sugar cane, and the dry, fibrous components, such as trash, dry leaves, etc. The green components are characterized by their content of juices containing sugars and the dry components by their low density and highly varied shape.

In general, harvest wastes have a high content of fibres and few proteins. By the use of fermentation processes, it is possible to improve their protein content and nutritive value. The low density of the wastes affects their transportation, so that in some countries methods are being studied of separating the various types and compacting them in order to improve their handling characteristics and reduce handling costs.

It is known in the region that bagasse can be used in the production of a number of derivatives such as pulp and paper, boards, and furfural and in the generation of electricity, so that there is experience of its industrial use, storage and separation methods.

The fact that bagasse is suitable for use as a fuel and is traditionally used for that purpose in sugar factories creates a competitive situation when the development of the industry for the production of derivatives from this raw material is analysed.

In most of the countries that produce cane sugar, it is necessary to use all the bagasse as fuel and sometimes large quantities are also used as additional fuel.

The utilization of bagasse as a raw material in the derivatives industry makes it necessary to analyse the size of the sugar-mills and their distance from one another, the link between sugar-mills and factories for the production of derivatives, and storage, transportation and depithing methods.

When bagasse is intended for use as a raw material in pulp, paper and board making, pith, which in most cases represents between 30 and 40 per cent of total bagasse, is obtained by depithing and can be used for generating steam or electricity and in animal feed.

In the region, molasses is used basically for the production of alcohol, yeasts, lysine, citric acid and animal feed. The principal problem affecting the use of molasses is its availability, since it sells at high prices on the international market.

Molasses can be obtained directly from sugar-cane in the form of high-test molasses or invert molasses. It is also possible to obtain A molasses or B molasses in the sugar-production process.

Sugar-cane juice is used directly in the production of alcohol and in some cases for animal feed. These processes offer the possibility of obtaining surplus bagasse.

No very profitable use for filter cake has as yet been developed, but on the other hand it is necessary to dispose of it as industrial waste. In many countries of the region it is used for watering fields or in irrigation channels. It is used in concentrated form in Cuba and Colombia as cattle and pig feed. The production of refined wax from filter cake offers prospects owing to the diversity of its uses in adhesives, for coating food and fruit, for crafts activities, bitumens, cosmetics, polishes and other purposes. In the region, Cuba has a semi-industrial plant for the production of refined wax, oil and resins.

2. Analysis of the situation in the region

The sugar-producing countries of Latin America and the Caribbean have a broad raw materials base for the development and industrial processing of a large number of products. There is a close link between the production of derivatives and the cane sugar industry, not only because of the quantities of by-products that are generated in the main industry but also because of the economic links between the processes, so that, among other factors, the size of the sugar-mills, the distance between them, the degree of agricultural and industrial modernization are important.

The availability of by-products is the determining factor in the industrial processing of derivatives, since the latter are generated as a logical consequence of sugar production and there is unquestionably a strong interrelation between the industry and its by-products.

Many examples of the development of different derivatives can be quoted in the region although if one considers the production of sugar and that of the by-products that are obtained as a logical consequence of their production, there is still great potential for the industrial processing of sugar-cane and its by-products. With regard to the industrial processing of derivatives, it can be observed that these and sugar are not considered together as lying within one sector, but that some of them are analysed in isolation, without taking into account the benefits that could be yielded by integrated development.

In most of the countries, with the exception of Brazil, where the production of alcohol is closely connected with that of sugar, there is no integrated approach to sugar and derivatives either. Generally, the sugar-mills sell off the bagasse and molasses, and sugar-producers are unaware of the benefits of their industrial use.

For the purpose of analysing the development achieved with regard to derivatives in the region, four major fields will be defined:

- Alcohol as a fuel and alco-chemistry;
- The utilization of sugar-cane by-products and derivatives for animal feed;
- The utilization of bagasse as a fuel, for energy generation, and the production of pulp and paper, boards and furfural;
- Other derivatives.

3. Alcohol as a fuel and alco-chemistry

Alcohol has traditionally been distilled in the sugar-cane growing countries, basically for the production of beverages and spirits for export and for highly specific uses in the perfumery and pharmaceutical industries. As from the 1970s, the traditional production of alcohol changed in the region and throughout the world with the introduction of Brazil's policy to produce alcohol as a substitute for petrol, accompanied by vigorous development of the alco-chemistry industry, i.e. the production of alcohol derivatives. Brazil has now 4.5 million ha of land in use for the production of sugar and alcohol and its planned output of alcohol in the present season is 13 billion litres. Brazil's policy with regard to alcohol is fully supported by the Government, this support being combined with vigorous development of the mechanical engineering industry.

Other countries in the region have substituted alcohol for petrol, including the following:

Argentina, which produces 495 million litres of anhydrous alcohol per year, basically for the domestic market;

Costa Rica sold 21 million litres of alcohol to the United States in 1986. It has also installed a dehydration plant with a capacity of 72 million litres to permit the purchase of hydrated alcohol and the production of anhydrous alcohol for export;

Bolivia produces 25 million litres of alcohol, which it uses as a substitute for petrol.

In other countries of the region, such as Honduras, Mexico, the Dominican Republic and Panama, among others, projects are being studied and analysed for the production of alcohol as a petrol additive, as a complete petrol substitute or for export to the United States.

The average cost of production reported in Brazil is 0.20 cents per litre. A distillery with a capacity of 120,000 litres/day has an average cost of between $US 6 and 7 million.

When, as in Brazil, alcohol is produced directly from sugar-cane, 3 kg of surplus bagasse is generated per litre of alcohol in independent distilleries. This bagasse is used in Brazil basically as a fuel for other industries and in some cases for electricity generation and as hydrolysed bagasse for animal feed.

The origin of alco-chemistry in Brazil dates back to 1920, when small quantities of acetic acid, ethyl ether and ethyl chloride were produced. At present, ethylene, acetaldehyde, acetic acid, butanol, butyl acetate and other chemicals are produced from alcohol. There are also projects for the production of other substances and for pilot plants.

In Peru as well there is a plant at Paramonga with an annual production capacity of 7,200 tons of PVC. It has four units for the manufacture of the final product: ethylene, dichlorethane, monomer and polymer plants. 2,000 tons of acetic acid is produced from alcohol and is used as raw material for the ethyl acetate, normal butyl acetate and isobutyl acetate industries.

The development of an alco-chemistry industry can be recommended in some developing countries because the plants are smaller in size than other plants in the chemical industry, require less investment and can be established in areas where the raw materials are available locally.

4. The use of sugar-cane by-products and derivatives for animal feed

The manufacture of feedstuffs from sugar-cane and its derivatives covers a wide range, from the simple use of wastes as such up to more sophisticated activities such as the production of lysine.

One of the advantages of basing animal feed production on the cane sugar industry is the low cost of the investments involved. Another factor to be stressed is the experience gained in the region by a number of countries such as Cuba, Colombia, the Dominican Republic and Brazil.

In Cuba, animal feed production on the basis of the cane sugar industry has been developed vigorously. The substances used for this purpose are sugar-cane direct, and mixtures of molasses and urea, and of molasses, urea and bagacillo, and predigested bagacillo; also, harvest wastes are processed, filter cake being dried for use as cattle-feed. There is also production of forage yeast, protein molasses and saccharomyces yeast; the production of cane syrup and intermediate molasses is under study.

Brazil produces hydrolysed bagasse, which is mixed with other products for use as feed for cattle when they are fenced in.

In Colombia, sugar is used as replacement poultry feed, and great progress has also been made in producing animal feed on the basis of the cane sugar industry.

In the La Romana sugar-mill in the Dominican Republic, there has been vigorous development of cattle-feed production from cane sugar industry by-products.

In Mexico as well, cattle-feed is produced from molasses and there is a plant for the production of 7,000 tons/year of lysine. This lysine plant is the only one reported in the region.

In almost all countries of the region, animal feed has been produced to a greater or lesser extent from cane sugar industry wastes. In the production of animal feed from cane sugar industry by-products, there must be closer integration between cattle farmers and sugar producers.

Various research projects have been under way for a number of years in several countries, principally Cuba, the Dominican Republic and Colombia, with the object of ascertaining the genuine potential of sugar-cane and the most appropriate handling and processing system. There have also been numerous nutritional research projects on the basis of which it can now be stated that sugar-cane can be the source par excellence for animal feed in the tropics.

5. The utilization of bagasse as a fuel, for energy generation, and the production of pulp and paper, boards and furfural

The high price of petroleum and its availability indicate a change in the criteria established with regard to the industrial use of bagasse. In most of the cane sugar producing countries, when bagasse has been industrially processed, it has been replaced as a fuel by petroleum products, thus increasing raw material prices. On the other hand, when surplus bagasse is used, only half the amount is available, so that new criteria must be found for the study of plant capacity and for investigating economies of scale by comparison with the costs of transportation and the replacement of bagasse as a fuel.

In the region, there are reports of paper production from bagasse in Argentina, Brazil, Colombia, Cuba, Mexico, Peru and Venezuela. The production of printing and writing paper from bagasse offers no difficulty and installations have been in existence for several decades.

Recently, three countries, Argentina, Mexico and Peru, have constructed plants with capacities in the 100,000 tons/year range for the production of newsprint from bagasse.

In this context, special mention should be made of the Tucuman newsprint plant, which has improved and optimized its original technology and produces paper to satisfy the needs of the domestic market and some quantities for export.

The investment cost of the plant was $US 300 million per ton; under present circumstances, prices do not cover total costs - only the variable costs but not the fixed costs. Also, the products must be exported to nearby countries so as not to burden the price with freight costs. Newsprint from Tucuman supplies 110 Argentine daily newspapers and its share of the local market has risen to 35 per cent. This newsprint has also been exported to a number of countries, such as the United States, Brazil, Venezuela, Peru, Uruguay, Paraguay, Bolivia and Thailand.

The investment cost of the Mexican newsprint factory was approximately $US 100 million. At the moment, it produces newsprint by the conventional soda process and exports most of its output, principally to the United States, Central America and Brazil.

The newsprint factory installed in Peru has closed down owing to some problems, chiefly in the economic field.

In Venezuela, a technology has been developed for the production of newsprint from bagasse, although there are still problems with the rotary printing presses.

In Cuba, a semi-industrial plant for the production of newsprint with a capacity of 9,000 tons/year was installed at an investment cost of $US 25 million. In this plant, the chemicals are not processed for re-use and low production costs for paper are reported.

There has also been some development of the production of boards in the region, although in certain countries such as Jamaica and Mexico the plants installed are not working. Cuba reports the existence of seven plants with a capacity of 275,000 m^3/year.

Special mention should also be made of the plant installed in Venezuela, where the boards are used in making furniture and in the construction industry.

There is a 40,000-tons capacity plant in the Dominican Republic for the production of furfural from bagasse, which operates basically for export. Brazil has a plant with a capacity of 3,500 tons/year; furfuryl alcohol is also produced.

Much research has been carried out in Cuba on furan derivatives and there is a project to install a furfural plant in the near future.

An important feature of the production of furfural is the high consumption of bagasse per ton of output. The investment for a 5,000-ton plant is approximately $US 20 million, and production costs are $US 800-1,000 per ton.

Other derivatives

In addition to those indicated above, other derivatives are produced in the region, a fact that it is useful to mention in this paper, since its principal purpose is to show the progress that has been made in this field.

Baker's yeast is produced in many countries of the region. In Mexico and Brazil, citric acid is produced from sugar and monosodium glutamate from molasses, both by fermentation. Monosodium glutamate is also produced in Peru.

Vinasse is concentrated in Mexico, and research on its concentration is being conducted in Cuba and Brazil.

In Brazil, lactic acid, sorbitol, mannitol, fatty acids and sucrose esters are also produced. In this country, in addition to the development of alcochemistry, a strong trend towards the development of sucrochemistry can also be observed.

In Cuba, dextran is produced from sugar and refined wax from filter cake, and there is a semi-industrial plant that produces dissolving pulp from bagasse.

The countries of the region are also studying the most efficient way of utilizing the wastes of the plants established, and efforts are being made to solve the problems of environmental pollution and to find solutions for fertilization, energy and other problems.

CONCLUSIONS AND RECOMMENDATIONS

- In the analysis of the situation in the region with regard to the diversification of the cane sugar industry in the Latin American and Caribbean countries, it should be emphasized that there is great potential for by-products and the industrial processing of a number of derivatives, and that these countries have some experience of research and development work.

- Diversification of the cane sugar industry not only provides a solution to the market situation for this product but also an answer to other problems faced by the sugar-producing countries.

- The direct utilization of sugar-cane and/or the by-products of the cane sugar industry provides feedstuffs, fuels, pulp, paper and board and also permits the development of the biochemical and chemical industries on the basis of an annually renewable resource.

- It follows from the above remarks that it is desirable to implement an interregional programme that would contribute towards reducing costs in the industry, raising efficiency in the technological sphere and in the use of fuels, expanding the production of derivatives and promoting integration in this context, thus developing the present cane sugar industry.

- It is also necessary to create an infrastructure capable of promoting methods and systems for technical co-operation and exchange of knowledge and experience that will provide the countries, institutions and officials with the necessary elements to permit rapid decision-making, taking into consideration the particular conditions of each country.

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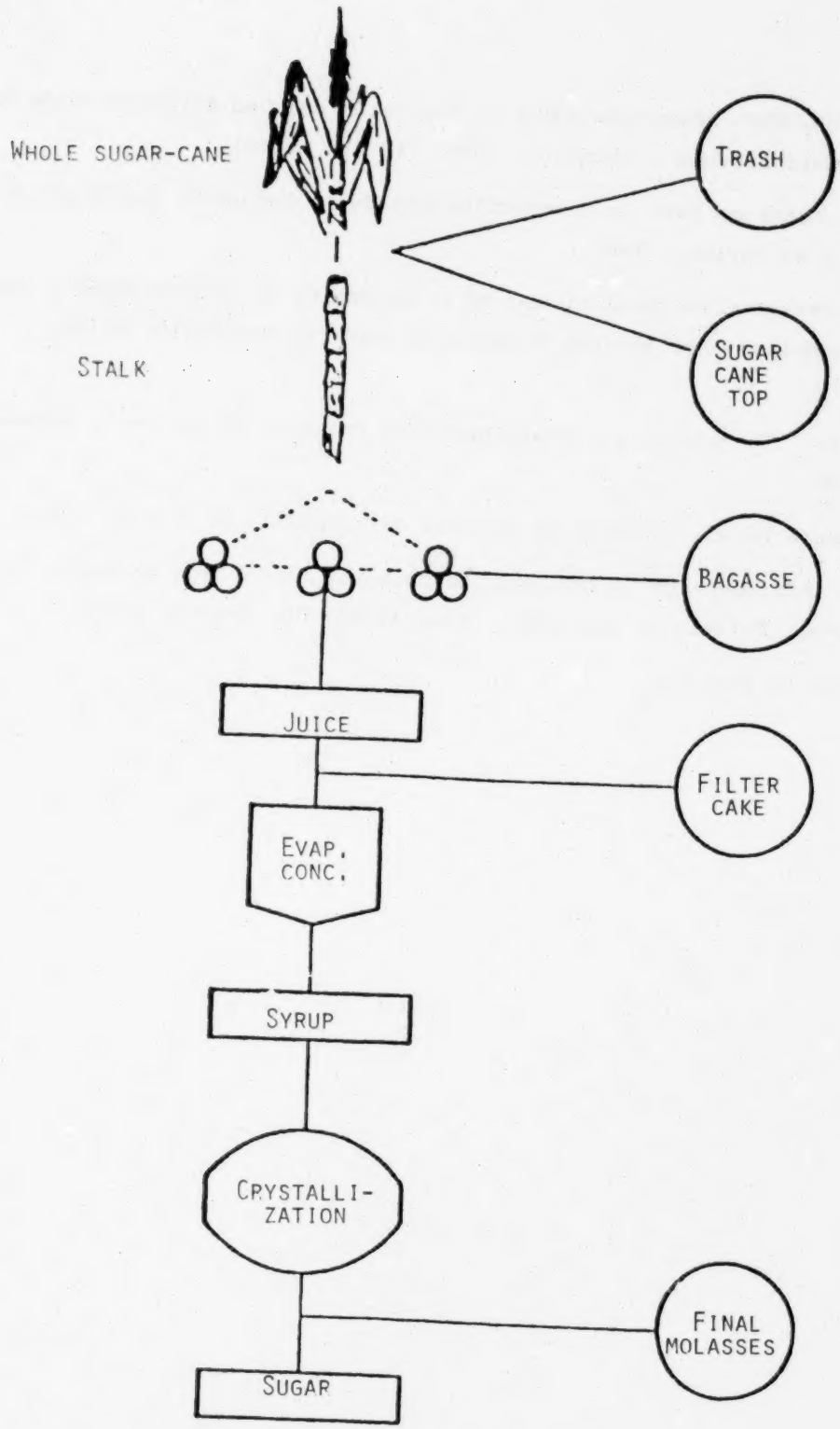
WHOLE SUGAR-CANE
TRASH
STALK
SUGAR CANE TOP
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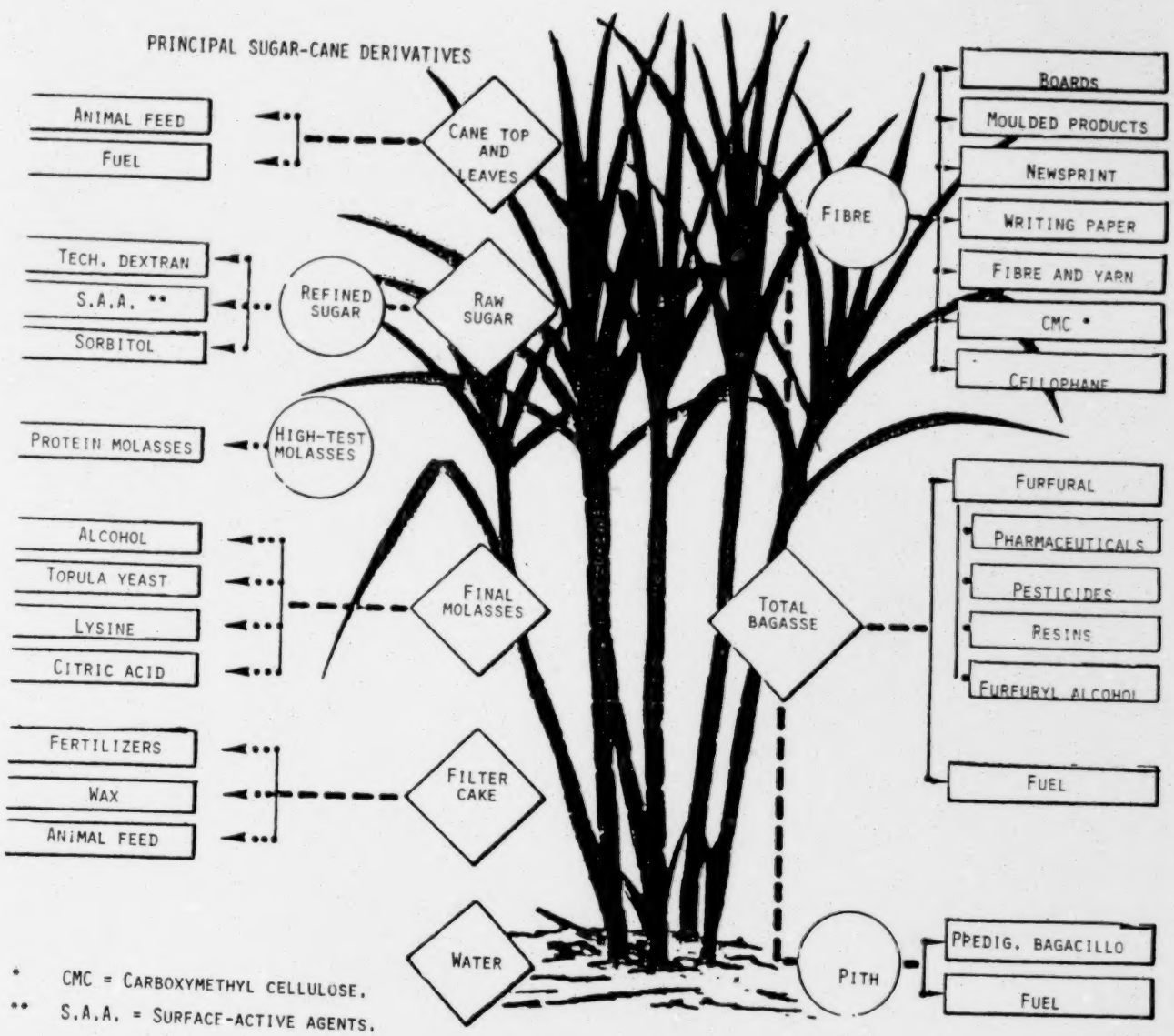
JUICE
FILTER CAKE
EVAP. CONC.
SYRUP
CRYSTALLI-ZATION
FINAL MOLASSES
SUGAR


PRINCIPAL SUGAR-CANE DERIVATIVES
ANIMAL FEED
FUEL
CANE TOP AND LEAVES
TECH. DEXTRAN
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SORBITOL
REFINED SUGAR
RAW SUGAR
PROTEIN MOLASSES
HIGH-TEST MOLASSES
ALCOHOL
TORULA YEAST
LYSINE
CITRIC ACID
FINAL MOLASSES
FERTILIZERS
WAX
ANIMAL FEED
FILTER CAKE
WATER
FIBRE
BOARDS
MOULDED PRODUCTS
NEWSPRINT
WRITING PAPER
FIBRE AND YARN
CMC *
CELLOPHANE
TOTAL BAGASSE
FURFURAL
PHARMACEUTICALS
PESTICIDES
RESINS
FURFURYL ALCOHOL
FUEL
PITH
PREDIG. BAGACILLO
FUEL
* CMC = CARBOXYMETHYL CELLULOSE.
** S.A.A. = SURFACE-ACTIVE AGENTS.

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DIVERSIFICATION OF SUGAR-CANE*

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INTRODUCTION

The production of sugar as a product both for export and internal consumption is an branch of the economy of strategic importance in a growing number of underdeveloped countries.

In the Latin American region sugar-producing countries were receiving, at the beginning of the present decade, approximately $4,000 million from the sale of sugar on different markets, these exports taking third place among internationally marketable products. At the present time the earnings have dropped to a third and the predictions are that they will continue to do so.

For several decades sugar has been a product with high price fluctuations and with a market creating difficult conditions for the exporters. These circumstances have been aggravated by a combination of negative factors which have caused the consumption figures to fall and the prices to stay below the profitability limits for increasingly longer periods of time.

The protectionist policy of the European Economic Community and the American legislation protecting internal products have been the factors that have weighed most heavily over the last few years upon the delicate situation in the sugar market.

To these two factors, sufficient in themselves, one can add the production of JACF which has undergone very dynamic expansion, mainly in the United States, replacing sugar in its chief traditional uses; and together with this go the health campaigns which claim that sugar is one of the agents causing cardio-vascular disease.

The producer countries are facing the reality of an imminent collapse of the international market, deterioration of the exchange value of sugar, and the consequences of it for their economies. Faced by these difficulties, they see diversification of the use of sugar-cane as the most viable alternatives, since it will make it possible to broaden the range of production for other than sugar markets at more favourable prices.

In Cuban conditions the diversification of sugar fits in with a strategy which has been put into practice for more than 25 years, and for which at the present time there are some 40 industrial plants and another 10 at the investment stage, which makes the country one of the most advanced in the use of by-products from a sugar industry and sugar-cane growing. These experiments and their results are reviewed in this paper.

1. SUGAR AS A PRODUCT OF INTERNATIONAL MARKETING

The world capacity for the commercial production of sugar of all types is reckoned at some 115 million metric tons, thereby exceeding by 15 million tons the present consumption, which remains at a little more than 100 million tons, while the existing stocks have grown to such an extent that they amount to around 40 per cent of the production, thereby doubling the acceptable levels. The installed capacity exceeds the consumption estimated by FAO for the year 1990, which optimistically places the demand at 110 million tons.

The sugar consumption index has been marked by drastic changes over the last 15 years in the areas of demand, in such a way that while the countries with a developed market economy have declined over this period, the socialist countries have stepped up their consumption by a little more than 50 per cent, and the underdeveloped countries have virtually doubled it.

The production, consumption and stocking level achieved in the present decade are influenced by a combination of factors which have been in effect negative.

The absence of a sugar agreement as an efficient instrument for establishing a relationship between producers and consumers in the search for stable prices has had an impact that, even while affecting the price trends, cannot be regarded as a determining factor.

At the present time, of the total sugar produced only 25 per cent is sold on international markets and barely half of that is subject to the market prices, with the remainder coming under special agreements between countries.

An important factor has been, however, the protectionist policy of the EEC and the United States of America, which have kept internal prices above those of the international market by granting various forms of subsidy, limiting the import quotas and even exporting below the market price. The United States quota policy made it possible to place some 3 million tons on the Latin American market scarcely five years ago, and for the present year, 1987, these exports will be about 700 million tons; this means that the producer countries lose $1,000 million each year.

Similarly, one of the factors that has most likely exercised considerable influence on the world market has been the role of exporter played by the EEC since the middle of the 1970s; it is at the present time placing around 4 million tons with prices that are subsidized.

Some underdeveloped countries have in the mean time been creating situations aimed at protecting the official policies of supporting the creation of new production capacities to ensure self-sufficiency.

A contribution to the dynamic development is made by the new sweeteners of the fructose syrup type; they emerged as commercial products 10 years ago and in the United States today represent a production of 5 million tons (dry base), which covers around 35 per cent of the market; they are produced at about 20 plants which utilize for this purpose from 5 to 10 per cent of the maize produced in the country. By 1990, JMAF should represent about 10 per cent of the total quantity of sweeteners consumed in the world, according to the predictions made by specialist organizations.

A new situation has been arising in the international market with the shift in the demand of importers from raw sugar to white sugar. The refined variety, which barely used to attain 25 per cent of the market in 1970, currently occupies about 50 per cent and predictions show that before the end of the present century, virtually all the sugar sold on the international market will be white sugar of various types.

This set of circumstances, which is influential in different ways, has exerted pressure on prices and their cyclic fluctuations, heralding longer periods of depressed prices. The latter have been marked by extreme fluctuations ranging from 1.5 cents per pound in 1968 up to 60 cents in 1974. On the other hand, the average prices of sugar at international level have been considerably below the cost of production, which is reckoned to be about 15 cents.

While all these phenomena occur in the international field, the Latin American region, which contributes a little less than a third of the entire amount of sugar produced - and this means one of its principal sources of foreign currency - shows a new trend in the destination of its produce; it is now going basically for

internal consumption, a little more than 40 per cent being exported to markets different from the traditional ones of 10 years ago when the United States was the main customer, but is now only marginally so and by 1990 will not appear on the lists of sugar importers at all.

This overall view of the production, marketing and pricing of sugar suggests that the international market is facing a fully-fledged crisis, which shows up in a reduction in the volume of marketable sugar; in the low prices prevailing for long periods; in the protectionist policies pursued, which are increasingly damaging, in the existence of production capacities which exceed the demand, and in the dynamic development of new competitive sweeteners which are ousting sugar.

This gloomy prospect for sugar-producing countries could undergo a complete change if diversification strategies suited to the characteristics and conditions of each enterprise and country were adopted and if, using sugar-cane as a raw material with abundant possibilities, we could select among the different alternatives those proving most technically and economically viable.

2. BACKGROUND AND PRESENT POSITION OF THE CUBAN SUGAR AGRO-INDUSTRY

Sugar production began in Cuba at the end of the sixteenth century and since that time the course followed historically by Cuban sugar production can be divided into five periods.

The first of these corresponds to the pre-industrial phase which stretched from the end of the sixteenth century until the time when Havana was taken by the English in 1762, and is marked by a rapid increase in the number of sugar mills. From that time up to the middle of the nineteenth century, under the influence of the industrial revolution there were introduced into agriculture and industry the technological changes which mark the second period. At that time there were slightly more than 1,300 rudimentary sugar mills which used to produce approximately half a million tons of sugar. Cuba had by then become the greatest sugar producer in the world.

The third period runs from 1860 up to the end of the War of Independence between Cuba and Spain at the end of the nineteenth century, when the mills suffered greatly as a consequence of this episode in history. The emergence of the pseudo republic during the first three decades of the new century, under the protection and with the backing of American capital, brought about a major industrial concentration and reduced the number of sugar refineries to 166. At this stage there followed a crisis in the industry through the fall in sugar prices, the stagnation in production and the unfavourable type of agriculture, which lasted up to the time of its nationalization in 1960.

The last period starts from the victory of the revolution and can be divided into different stages: the first involves the introduction of revolutionary legislation and the nationalization of private companies; the second relates to the sugar development programme, culminating with the harvest of 1970 when a record production figure was reached; the third stage covers the 70s and is characterized by the creation and consolidation of the technical-material base for supporting development programmes; during this there was further mechanization of cane sugar growing and there were set up, after 50 years, the first sugar refineries, designed and constructed by Cuban engineers; in addition to this there was a major advance in the production of derivatives; and a fourth stage has been going on since 1980 with unification of cane sugar growing with the sugar industry, leading to a higher form of organization - the agro-industrial complexes.

The sugar agro-industry employs 400,000 workers and is composed of 156 agro-industrial complexes, 16 sugar refineries, of which seven are for direct white sugar, and about 40 plants for derivatives, more than 150 animal fodder plants, an infrastructure of more than 1.7 million hectares of land, 45,000 tractors, 4,300 sugar-cane combines, 800 centres for shipping and cleaning the sugar-cane, 7,700 km of railway, 1,000 locomotives, seven modern harbour installations with a daily export capacity of 75,000 tons of bulk unrefined sugar, and 12 plants for machine making.

The technical development of the production of sugar and its derivatives is backed up by four specialized research institutes, eight stations for the development of varieties, two design institutes, and various technological faculties and institutes relating to sugar.

The sugar agro-industry is the principal creator of exportable commodities and during the last five-year period the products of the sugar industry have been about 80 per cent of the country's total exports and about 20 per cent of the overall social product; Cuba is the greatest world exporter of sugar and covers about a quarter of all international sales and more than 10 per cent of its exports go to the free world market. The Cuban sugar economy is one of the most efficient among the sugar producing countries, principally in the industrial field, where yields higher than 11 per cent are gained and the sugar recovery is of the order of 85 per cent; all of this is accompanied by harvest mechanization levels of more than 60 per cent, which normally bring about a decline in industrial efficiency, but in Cuban conditions this has not been significant.

The production of raw sugar in Cuba is self-sufficient from the standpoint of energy, and a programme is under way for the conversion of the industry into a net energy producer. The last sugar-cane harvest provided the national network with approximately 10 per cent of the electricity generated in the country during the harvesting.

Cuban sugar production has been absorbing the new trends on the international markets in the shift in demand from raw to refined sugar and is now at the stage of introducing more advanced production techniques for white sugar that have been established internationally. The growing of sugar-cane covers more than 1.7 million hectares with an average yield of 55 t/ha. The sugar production per hectare-year attained is of the order of 6.4 t, above the world average of 4.4.

Cuba's agro-industrial sugar activity is progressing under conditions of relative efficiency and a technological level that is fairly high; this makes it possible to take advantage of major reserves available chiefly in the agricultural area.

3. EVOLUTION OF THE SUGAR DERIVATIVE INDUSTRY AND THE PRESENT SITUATION

The development of derivatives

The use of sugar-cane by-products at international level is relatively recent in the present century; their initial uses were the consumption of bagasse as fuel and molasses in animal feeds and in alcohol production.

The beginning of expansion of the derivatives, with the setting up of large industrial plants, began in the 1940s; that decade saw the deployment of significant technological efforts in the pulp and paper, fermentation and board industry, and it was at the end of the 1950s and beginning of the 1960s that the large-scale industrial application of the by-products began at international level.

The sugar derivative plants are spread over 20 countries and those that have attained the greatest development are for: pulp and paper, alcohol, board, animal fodder, furfural, yeast, lysine, monosodium glutamate and citric acid.

In Cuban experience the development of the derivatives, from the standpoint of raw materials, degree of processing and technological complexity, is characterized by four generations, the limits and scope of which are not exact and are fixed by convention.

The first generation relates to direct use of the by-products or derivatives with a low level of processing, in which minimum transformation of the original raw materials occurs; examples are the direct consumption of molasses by cattle, production of molasses-urea-fine bagasse (bagacillo), predigested fine bagasse and so on.

The second generation relates to production that uses the by-products and intermediate products of the sugar processing; it is characterized by technologies of low and medium complexity and results in derivatives with their own characteristics. Examples of this are the production of board, protein molasses, furfural, alcohol, pulp and enzymes.

The third generation covers products obtained through the chemical and/or biochemical transformation of second-generation derivatives and sugar; it leads to new products with properties that are different from the original raw material and is based on medium and high complexity technologies. Examples are: paper, CMC, ethylene, artificial fibres, yeast for human consumption, furanic derivatives, lignisulphonate organic acids, surfactants, and so on.

The fourth generation belongs to products obtained from the by-products, derivatives and sugar, resulting in precursors or intermediate products from other processes in which they are used as raw material. They are based on chemical and/or biochemical technologies of high complexity; examples are phytosterols, AD, ADD, amino acids, and grafted cellulose as a support for immobilized enzymes.

Evolution of the Cuban industry

The initial production of derivatives that attained the greatest development in Cuba related to alcohol and rum, which appeared at the end of the last century. The 1930s saw the beginning of the production of baker's yeast by a small plant and several initiatives were developed in animal fodder containing bagasse and molasses. In the 1950s plants were set up for the production of crude wax and in 1955 a dextram plant was started up. 1957 saw the beginning of pulp and paper production, while installations for manufacturing fibre board began operation in 1959.

At the time of the victory of the revolution there were 17 alcohol distilleries in the country, 16 of which are still in operation at the present time. In 1965 the first plant to produce Torula fodder yeast from blackstrap molasses started production.

In the middle of the 1970s and beginning of the 1980s there was considerable expansion of the sugar derivative industry with the installation of nine Torula yeast plants, three bagasse board factories, two pulp and paper plants, and more than 150 small animal fodder plants; a new alcohol distillery with the production of Torula yeast from must was set up and began refining crude sugar-cane wax.

Present situation

There are some 40 sugar derivative plants and more than 150 facilities in the country for the production of animal fodder based on different by-products. These capacities make Cuba a sugar producing country with the broadest range of derivative products. For the production of Torula yeast with a 45 per cent protein content for animal fodder there are 10 plants with an installed capacity of 100,000 tons per year. This capacity is the highest in existence for production from blackstrap molasses; it was set up in the country in 1965 when the first unit of the "Ciro Redondo" Refinery was installed. Later on, in the 1970s, nine plants were purchased and set up with a capacity of 40 t/d each. These plants operate efficiently and their products are basically intended as poultry and hog fodder as well as for export to the socialist camp.

New developments in the use of Torula yeast have been geared to the production of a protein concentrate from intermediate molasses as hog fodder - protein molasses - of which approximately 70,000 tons are being produced at present. Similarly, technologies have been developed for reducing the nucleic acids in yeasts and making them suitable for direct human consumption. A new plant with a capacity of 8,000 tons will be started up at the end of 1987.

The alcohol industry has 16 plants with a capacity of 150 million litres per year, which is intended for domestic fuel, the production of beverages, the pharmaceutical and cosmetic industry and for export. The investment programme under way provides for the modernization and installation of new distilleries designed and constructed in the country, with the possibility of recovering saccharomyces yeast and carbon anhydride. The use of juices from filtered sludge for the fermentation of alcohol has been introduced. Similarly, work is in progress on the use of dregs from the distilleries as animal fodder. New technologies have been developed to speed up the maturing of tafia and the production of light rums for internal consumption, five such plants being in operation.

There are five pulp and paper factories with an installed capacity of some 17,000 tons. Three of these - Damují, Técnica Cubana and PROCUBA - were set up the 1950s, while Cuba-9, a pilot plant of semi-commercial capacity, began operating in 1983 and the Uruguay Combine, the largest of the plants existing, was started up in 1984. The main product of these plants is printing and writing paper and it is only Cuba-9 which manufactures newsprint for experimental purposes. The technologies for different types of paper with a high bagasse fibre content predominate in Cuba, a country which has the support of research and development teams with broad experience and experimental facilities of international standard.

There are in operation seven plants for producing bagasse board with an installed capacity of 240,000 m^3 per year. The first three plants were built in the 1950s and one of them - the Amancio Rodríguez - has technology suitable for manufacturing fibre board. At the end of the 1970s another three plants were set up with modern technology for continuous processing and single-plate presses. This set of facilities makes Cuba a country with a high installed capacity as well as one with the greatest diversity of technology and equipment. Production involves a high level of quality, in accordance with international standards; the board constitutes a commodity for which there is ample demand and it is used throughout the country for making furniture, in the construction industry and also for export. Work is being done to design new types of board with a low content of free formaldehyde, phenols with high resistance to humidity and cement board resistant to weather.

In animal feeds, sugar-cane by-products and derivatives are tending to be used more and more. During the last harvest the amount of fodder used for bovines constituted 34 per cent of the total consumption and this figure has been growing at an annual rate of more than 10 per cent over the last five years. More than 10 types of fodder are being produced currently and another 10 are at different research and development stages.

The development of sugar products and by-products as fodder has permitted the steady and very fast growth of food sources for bovines and they are beginning to be significant also in hog fodder.

The evermore important role played by by-products in animal food has called for the development of silage, storage, drying and other methods of preservation as well as a tendency to site food consumption centres close to where the supply is, thereby making it possible to extend the practice of stabling for long periods. The developments envisaged will require a great deal of participation by engineers and construction of domestic equipment.

Prospects for development suggest that by 1995 the derivatives of the sugar agro-industry will account for 45-50 per cent of total amount of fodder intended for bovines and hogs. The ratio of tons of animal fodder to tons of sugar produced has gone up from 0.3 t/t in 1981 to 0.6 t/t in 1987, and according to prediction will reach 1.0 t/t in 1990. It is estimated that this ratio could potentially rise to about 3 tons of fodder to a ton of sugar produced.

Cuba has facilities and plants for a series of derivatives, the production of which is unique: among them are predigested fine bagasse, protein molasses, wax, dextran and straw/molasses mixtures in different forms. This means that the country possesses the greatest diversity of production and the most varied knowledge of the way in which to utilize the by-products, even though other countries are better versed in some of the special technologies.

The development programme for the derivatives provides for the setting up of several plants to broaden the diversification of the Cuban sugar industry, basically geared to the creation of a national fodder base and the production of items for export.

Over the present five-year period 1986-1990 investments are being made in plants producing lysine, furfural, citric acid, wax, dextran, enzymes, surfactants, protein molasses and by-product fodders. The bulk of these facilities will be constructed with domestic technology and design and with incorporation of equipment built in accordance with the capacity available in the country.

4. STRATEGIC ASPECTS OF DEVELOPMENT OF DERIVATIVES

The low prices of sugar and its decline as an export product for the international market compels us to look for alternatives by which to compensate for the losses caused by this situation as well as to develop new products for export that make foreign trade more flexible. Over the last few decades there have been many initiatives in the region for the use of by-products and to employ them to broaden the range of possibilities for the sugar economy; most countries have set up the production of derivatives and are planning new investments. Of all the efforts made, those of Brazil are the most important in terms of their extent and impact on alcohol as a fuel and this has been done in accordance with the country's conditions and features.

Among the plants cultivated for trade, sugar-cane possesses the greatest qualities both as regards its photosynthetic uptake of solar energy, and its

capacity for producing green matter composed of sugars, starches, protein and lignocellulose compounds, all of these raw materials for a broad range of economically important products.

One hectare-year of sugar-cane with an average yield is able to produce 100 metric tons of green matter, more than double that of the majority of other plants; in terms of total energy, more than 1,000 metric tons of oil equivalent, and when considered as metabolizable energy this is 75,000 megacalories, or several times more than any other crop under the same conditions.

It should be borne in mind that the values applied correspond to the commercial varieties in use; these figures may even be greater when dealing with the varieties expressly developed for the production of derivatives with the possibility of attaining a higher content of green matter, fibre or simple sugars within shorter times. Genetically, this is feasible and can be done with the present cross-breeding techniques with greater stress on the species of saccharum and similar genera.

The possibility of obtaining large amounts of surplus bagasse as a result of improving the energy efficiency of the refineries, which, added to the concentrated agricultural residues at the storage and cleaning centres, ensure a cellulose residue potential that could guarantee the development of many forms of derivative production, chiefly those associated with animal feeding, without necessarily competing with the production of electricity.

The development of derivatives should lead to the greatest possible diversity of production with the greatest aggregate value, on the basis of technological criteria and flexible forms of production employing different intermediate products from the sugar processing and saccharose as raw material, according to the conditions of the demand and the price of the product on the international market.

The strategic criteria to be taken into account are:

1. Selection of alternatives by which to utilize to the maximum extent cane sugar and its by-products

It is here a matter of selecting the production alternatives permitting the highest revaluation possible of cane sugar and the by-products as raw materials. Furthermore, there should be consideration of the alternatives for using varieties with characteristics geared to the production of derivatives which have a high fibre content or attain their maximum growth or simple sugar content within a shorter period of time than the traditional varieties.

2. Integrated technological schemes for the alternative and/or simultaneous production of sugar and sugar derivatives

The production of derivatives should begin to take shape along with the technological schemes that are interconnected from the standpoint of processing and energy consumption. This will make it possible to use the poorest juices from different stages of milling and filtering for fermentation processes, to use the intermediate molasses, to utilize bagasse with partial sugar extraction, and other possible combinations.

These schemes should be conceived in the form of closed technological cycles in such a way as to make use of all the residues for conversion into useful products at the same time as recycling the water inside the plants and avoiding environmental contamination.

3. Improvement in the energy efficiency of the sugar industry

An essential condition for economic development of derivatives is to have electricity at the lowest possible cost and at the same time to have surplus bagasse.

Both objectives are compatible with the energy properties of sugar-cane as a raw material and in terms of the potential of the refineries for improving their energy efficiency by means of moderate investments based on known technologies.

4. Flexible scaled economy determined by the availability of raw materials and/or local demand

In a large number of alternatives, chiefly those concerning animal feeds, the scaled economies should match the available amounts of raw materials on the site in such a way as to simplify transportation and handling and to avoid the cost involved in such operations. Similarly, the scales should be influenced by local demand.

These considerations do not clash with the needs of large-scaled economies which are required by certain forms of production using high complexity technologies, such as pulp and paper, bagasse board and so on.

5. Priority development for animal fodder production

On account of the characteristics of cane sugar as a raw material, this development involves special conditions in order to meet the requirements of animal diet, used directly or employing harvest residues and industrial by-products. It is an advantage in this alternative that in most cases the investments are not high and the facilities required are not complex.

To these features one has to add the fact that the crops of sugar and installations for producing it are spread over different agricultural areas, where the cattle are usually of different types or where such can be encouraged.

This combination of factors plus the fact that most countries, with the exception of those possessing prairies or natural pastures, are compelled to seek national solutions to the problem of feeding their cattle, mean that the products involved in animal fodder should have the highest priority.

6. Production of export stocks or stocks for replacing imports

In view of the need to find new products to replace the sugar markets that are disappearing, derivatives should be used to encourage the replacement of imports and the build-up of exportable stocks by the setting up of plants for this purpose.

7. Diversification of derivatives and encouragement of new generations connected with feeding, pharmaceutical production and agriculture

Among the strategic priorities for sugar derivatives there should be included diversification of production by the introduction of production of derivatives of the third and fourth generation, based on advance technologies which can meet the requirements of such economic sectors as animal fodder, the pharmaceutical industry and chemical products for agriculture.

These alternatives will gradually be developed as the production of first and second derivative generations is expanded and a broader range of production with high economic value and exportable stocks is assured.

8. Investments with the fullest integration of engineering, designing and machine construction on a national basis

Cuba possesses a scientific-technological-industrial infrastructure with a relative degree of development that can serve as a support in the development of derivatives in such a way that the new facilities will for the most part have a high degree of national integration.

If employed on the broadest scale, this capacity will make it possible to decrease investment costs and to make developments most suited to Cuban conditions, as a result of which the implementation and start-up schedules will be more favourable.

As opposed to other sugar-producing countries, Cuba's principal export is secure on the socialist markets and the country has a strategic outlet for its development on the basis of its most abundant natural resource - cane sugar, a raw material which can be converted into a virtually unlimited number of derivatives demanding a modern economy.

Most of the Latin American countries and among them the sugar producers are engaged in the reconversion of their industrial economies in response to the opening up of new markets and to regional integration. This paper is meant to be a contribution to those endeavours by which to build the foundations for creation of stronger and less dependent economies.

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SOME ASPECTS OF UNIDO'S TECHNICAL ASSISTANCE ACTIVITIES IN THE SUGAR INDUSTRY*

Prepared by the
UNIDO Secretariat

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One of the problems faced by sugar industry in developing countries is its low price on the free market. There are several factors which may have contributed to this situation:

- from some 80 million tonnes in early seventies, the annual production of sugar has increased to close to 100 million tonnes in early and mid-eighties;
- introduction of sweeteners, other than sugar, particularly high fructose corn syrup, has resulted with stagnation or even reduction of sugar consumption in some developed countries;
- although sugar does not represent a major calory supplement in a daily diet, it is often the first one to be reduced by those who suffer from obesity and heart problems;
- due to economic problems and low buying power (living standard) in many developing countries, the consumption of sugar has not increased as expected; for many people sugar is still a luxury item which they can hardly afford;
- import restrictions and shortage of foreign exchange limit the consumption of sugar in some importing countries; increasing the consumption to the world average in only some of them, such as China and some African countries, would have considerable impact on sugar production and its price on the world market;
- support of domestic agriculture and sugar industry in some developed countries, with import restrictions, has resulted in a high price for the end consumer (several times higher than the free market price).

Due to these, as well as some other factors, there are sugar exporting countries trying to reduce sugar production while some importing countries

are increasing their production capacities. Under these circumstances, one can also note the tendency to:

- divert sugar production to alcohol in order to reduce surplus;
- reorganize and modernize (rehabilitate) sugar mills to operate as efficiently as possible;
- better utilize sugar industry by-products which in some cases may bring additional income to the sector.

This has also been reflected in technical assistance activities of UNIDO which is always based on official requests for assistance and therefore reflects to some extent priority criteria established by the Governments of the countries concerned. There have been several types of activities which are dominating:

1. Rehabilitation of sugar mills which are not operating efficiently and at full capacity, either because of outdated technology and equipment, shortage of spare parts, unskilled labour, or poor management, internal unrests, etc.
2. Better utilization of by-products, particularly bagasse (from sugar cane) and molasses, which may represent very useful raw materials for a variety of products, such as bagasse board, paper, furfural, yeast (both bakers' and fodder), alcohol (including rum), animal feed, organic acids, various chemicals, etc.
3. Rational energy utilization and therefore reducing the consumption of bagasse which, as a surplus, may be utilized for electricity and steam generation or for some other products.
4. Establishment or increasing the capacity of sugar industry development institutions which are involved in research and development activities as well as in training of industry personnel in specific skills.
5. Various activities related to the technological operation of sugar mills, maintenance and repair, corrosion prevention, manufacture of spare parts, etc.

Through years, technical assistance has been provided to a number of countries, such as Argentina, Cuba, Dominican Republic, Jamaica, Angola, Burundi, Congo, Mauritius, Morocco, Niger, Egypt, Syria, Lebanon, China,

Thailand, Viet Nam, etc. There were also meetings organized on the selection of equipment for the sugar industry, appropriate sugar technology for Africa, rational energy utilization in cane sugar industry, repair and maintenance of equipment in the sugar industry, and some other, more or less relevant to the sugar industry. All these activities, spread over many years, have had marginal effect on the development of the sugar industry, probably with a few exceptions of which some are only indirectly related to the sugar industry (bakers' yeast, animal feed, bagasse paper). In fact, considering the magnitude of investments, a number of people employed and the importance of the sector for some developing countries (Brazil, Cuba, Jamaica, Mauritius), all technical assistance provided so far could not make great impact on the countries' economy. However, it may have had an impact on some production aspects, either of sugar itself or of some products made from bagasse and molasses. The following are only a few examples:

- establishment of laboratories and pilot plant facilities for fermentation, biochemical additives and treatment of cellulosic material (bagasse), has resulted in the expansion of animal feed production based on bagasse and molasses (Cuba);
- identification of problems in bagasse board plant and recommendations on how to improve technology was aimed at improving the quality of boards for furniture industry (China);
- preliminary studies and assistance through expert services, enabled authorities to decide and go ahead with the establishment of cane sugar production (Morocco, previously only beet sugar producer);
- establishing bakers' yeast plant to supply yeast to the local bakeries should improve the quality of bread produced (Viet Nam);
- establishment of sugar development centre (Egypt) with a pilot plant and training facilities should contribute to upgrading the skill of plant personnel and apply some research and development results in practice;
- assistance provided in some very narrow fields of expertise, such as use of ion exchange for juice purification, introduction of computerized production control system, improving the yields in sugar, alcohol and yeast plants, have all one way or the other contributed to the better operation of the industry.

It might be interesting to mention two meetings organized by UNIDO and UNEP in one case, and UNIDO, GEPLACEA, OLADE and the Cuban authorities in the second case. The first meeting, Seminar on the Implication of Technology Choice in the African Sugar Industry, was held in Nairobi, Kenya, 18-22 April 1977. It dealt with social, economic, technological, investment, agricultural, environmental and energy aspects of sugar industry development. Comparison of small scale (open pan) and large scale (vacuum pan) sugar production was one of the main topics. It was interesting to note advantages and disadvantages of each system which should be carefully looked at before deciding on the establishment of new sugar plants. At that time, sugar production was still very attractive and there was considerable interest to establish new plants.

In principle, it was difficult to conclude that small open pan technology would be a better solution than large vacuum pan, and vice versa. Small plants are obviously less energy efficient, the quality of sugar is inferior, investments are small and employment per tonne of sugar produced is higher. Such plants may operate economically provided that labour wages are kept low. Also, there are regions and areas where infrastructure is adequate for large scale operations, unemployment is high and demand for quality is not particularly strong. Equipment manufacturers used to indicate that 3000 tonnes of cane per day capacity is minimum for economic and rational operation, this is probably based on the common size and capacity of individual pieces of equipment. Large scale operation is no doubt more energy efficient, quality of product is better, but requires very skilled operators for running and maintenance of the plant equipment, investments are high, etc. In many cases, the economics of sugar production for domestic market depend on the local sugar price determined by the Government authorities and import restriction. Sugar industry in many developed countries would not survive free competition from developing countries.

The second meeting, Latin American Workshop on Rational Energy Utilization in Cane Sugar Industry, was held in Cuba, 8-13 September 1980. When promoting the organization of such a meeting several years earlier, the response was not very enthusiastic. Sugar prices in 1974-1976 period were high and only late 1976, they fell down to a low level which everybody believed to be temporary. However, it is evident that this has not been temporary and in fact with some ups (1980|81) and downs, it has remained low until now. In any case, low prices of sugar on the free market in 1977-79 gave some thoughts to sugar exporting countries which realized that every effort should be made to reduce production costs, and rational energy utilization could be one of them, not so much directly but mor indirectly. Particularly, if surplus bagasse could be utilized economically for the production of other products which the country may badly need and which may bring some additional income to the sector. It was realized that energy consumption (primarily thermal) could be reduced through the appropriate selection of technology, better control of steam boilers (high pressure versus low pressure), partial drying of bagasse with exhaust gases, better heat insulation of all thermal equipment and piping, heat recovery, etc. Energy inventory however, was considered as the first very important step which would enable exact determination of how much and where the energy is consumed.

It was suggested that similar meeting be organized for Asian countries and may be, later on, for Africa, however, due to financial constraints, no action has been taken so far.